



INTERNATIONAL PRELIMINARY EXAMINATION REPORT  
(PCT Article 36 and Rule 70)

07 JUN 2005

Applicant's or agent's file reference XA1772	<b>FOR FURTHER ACTION</b> See Notification of Transmittal of International Preliminary Examination Report (Form PCT/PEA/416)	
International application No. PCT/GB 03/05555	International filing date (day/month/year) 18.12.2003	Priority date (day/month/year) 23.12.2002
International Patent Classification (IPC) or both national classification and IPC G02B26/06		
Applicant BAE SYSTEMS PLC		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.
2. This REPORT consists of a total of 7 sheets, including this cover sheet.
- ☒ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).
- These annexes consist of a total of 6 sheets.

3. This report contains indications relating to the following items:
- I ☒ Basis of the opinion
  - II ☐ Priority
  - III ☒ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
  - IV ☐ Lack of unity of invention
  - V ☒ Reasoned statement under Rule 66.2(a)(ii) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
  - VI ☐ Certain documents cited
  - VII ☐ Certain defects in the international application
  - VIII ☐ Certain observations on the international application

Date of submission of the demand  19.07.2004	Date of completion of this report  09.03.2005
Name and mailing address of the international preliminary examining authority:  European Patent Office - P.B. 5818 Patentlaan 2 NL-2280 HV Rijswijk - Pays Bas Tel. +31 70 340 - 2040 Tx: 31 651 epo nl Fax: +31 70 340 - 3016	Authorized Officer  Quertemont, E  Telephone No. +31 70 340-3078 

**INTERNATIONAL PRELIMINARY  
EXAMINATION REPORT**

International application No. PCT/GB 03/05555

**I. Basis of the report**

1. With regard to the **elements** of the international application (*Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17)*):

**Description, Pages**

1, 2, 4-12 as originally filed  
3, 3a filed with telefax on 08.02.2005

**Claims, Numbers**

1-21 filed with telefax on 08.02.2005

**Drawings, Sheets**

1-6 as originally filed

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

These elements were available or furnished to this Authority in the following language: , which is:

- ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).  
☐ the language of publication of the international application (under Rule 48.3(b)).  
☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

- ☐ contained in the international application in written form.  
☐ filed together with the international application in computer readable form.  
☐ furnished subsequently to this Authority in written form.  
☐ furnished subsequently to this Authority in computer readable form.  
☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.  
☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. The amendments have resulted in the cancellation of:

- ☐ the description, pages:  
☐ the claims, Nos.:  
☐ the drawings, sheets:

**INTERNATIONAL PRELIMINARY  
EXAMINATION REPORT**

International application No. **PCT/GB 03/05555**

5. ☒ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)).

*(Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)*

**see separate sheet**

6. Additional observations, if necessary:

**III. Non-establishment of opinion with regard to novelty, inventive step and industrial applicability**

1. The questions whether the claimed invention appears to be novel, to involve an inventive step (to be non-obvious), or to be industrially applicable have not been examined in respect of:

☐ the entire international application,

☒ claims Nos. 19-21

because:

☐ the said international application, or the said claims Nos. relate to the following subject matter which does not require an international preliminary examination (specify):

☒ the description, claims or drawings (*indicate particular elements below*) or said claims Nos. 19-21 are so unclear that no meaningful opinion could be formed (*specify*):

**see separate sheet**

☐ the claims, or said claims Nos. are so inadequately supported by the description that no meaningful opinion could be formed.

☐ no international search report has been established for the said claims Nos.

2. A meaningful international preliminary examination cannot be carried out due to the failure of the nucleotide and/or amino acid sequence listing to comply with the standard provided for in Annex C of the Administrative Instructions:

☐ the written form has not been furnished or does not comply with the Standard.

☐ the computer readable form has not been furnished or does not comply with the Standard.

**V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement**

1. Statement

Novelty (N)	Yes: Claims	7-16
	No: Claims	1-6,17,18
Inventive step (IS)	Yes: Claims	7-16
	No: Claims	1-6,17,18
Industrial applicability (IA)	Yes: Claims	1-18
	No: Claims	

**INTERNATIONAL PRELIMINARY  
EXAMINATION REPORT**

International application No. **PCT/GB 03/05555**

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**2. Citations and explanations**

**see separate sheet**

**Re Item I**

**Basis of the report**

- 1.1 The amendments filed with the letter dated 08.02.2005 introduce subject-matter which extends beyond the content of the application as filed, contrary to Article 34(2)(b) PCT.
- 1.2 The amendments concern amended claim 1 which relates to a deformable mirror comprising a first layer of actively deformable material, that is operable to deform the mirror as a result of transverse expansion or contraction of the material under the influence of a field applied across its thickness. The international application discloses (page 3 and original claim 1) a deformable mirror comprising a layer of deformable material attached to the substrate. Optionally, the deformable material comprises piezoelectric material and is preferably segmented (page 3, lines 17-20). The individual elements (18 on the drawings) can be made of either a single piezoelectric layer, a bimorph structure or multilayer elements (page 7, lines 16-18). Although it would be clear for a skilled person that these elements would be operable to deform the mirror as a result of transverse expansion or contraction of the material under the influence of a field applied across its thickness, as expressed in amended claim 1, the original application does not disclose however this effect, other than this effect being the result of piezoelectric material. Therefore amended claim 1 contains a generalisation that introduces subject-matter going beyond the disclosure in the international application as filed.
- 1.3 Hence amended claim 1 does not meet the requirement of Article 34(2)(b) PCT.
- 1.4 Amended independent method claim 20 refers to amended claim 1 and therefore does not meet the requirement of Article 34(2)(b) PCT.
- 1.5 Amended claims 2-19 and 21 are dependent on amended claims 1 or 20 and therefore does not meet the requirement of Article 34(2)(b) PCT.
- 1.6 The International Preliminary Examination Report has therefore been established on the basis of the original set of claims.

**INTERNATIONAL PRELIMINARY  
EXAMINATION REPORT - SEPARATE SHEET**

International application No. PCT/GB 03/05555

**Re Item III**

**Non-establishment of opinion with regard to novelty, inventive step and industrial applicability**

Claims 19-21 contain reference to accompanying figures in contradiction to Rule 6.2(a) PCT.

**Re Item V**

**Reasoned statement under Rule 66.2(a)(ii) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement**

1. Reference is made to the following documents:

D1: US-B1-6236490

D2: US-A-3904274

D3: US-A-4655563

D4: Ikramov A.V. et al : "Bimorph Adaptive Mirror", Soviet Journal of Quantum Electronics, American Institute of Physics, Woodbury, NY, US, vol. 22, no. 2, 1 February 1992 (1992-02-01), pages 163-166.

2.1 Claim 1 does not satisfy the requirements of Article 33(2) PCT, because the subject-matter of claim 1 is not new.

2.2 Document D1 discloses (figure 2 ; the references in parentheses applying to this document) a deformable mirror (10) comprising a reflective surface (18A) provided on a substrate (18) and a layer of deformable material (the deformable material may be considered to be either the array of actuators (20) or the layer (14)) attached to the substrate that is operable to deform the mirror and wherein the substrate (18) is supported by an actuator (16) that is operable to deform the mirror.

2.3 Hence the subject-matter of claim 1 is not new (Article 33(2) PCT).

2.4 The applicant should be aware that the features of claim 1 are also disclosed in document D2. D2 discloses (figure 2 ; the references in parentheses applying to this

document) a deformable mirror on a substrate (34), a layer of deformable material (26) wherein the substrate is supported by an actuator (one of the individual elements of the piezoelectric wafer 26). Hence the subject-matter of claim 1 is not new (Article 33(2) PCT) with respect to D2 as well.

- 3.1 Independent method claim 17 does not satisfy the requirements of Article 33(2) PCT, because the subject-matter of claim 17 is not new. Document D1 discloses (column 2, lines 8-32) a method of correcting phase variations, wherein the actuators (16) are moved to correct Zernike modes at or below a threshold order (i.e. lower frequency wavefront errors) and the deformable material (the layer formed of an array of actuators 20) is moved to correct Zernike modes above the threshold order (i.e. higher frequency wavefront errors).
- 3.2 The applicant should be aware that claim 17 is also anticipated by document D3 (figure 2 and column 3, line 49 to column 4, line 16).
4. The additional features of claims 2, 3, 6 are disclosed in document D1 (figure 2). Hence the subject-matter of claims 2, 3, 6 lacks novelty (Article 33(2) PCT).
5. The additional features of claim 4 and 5 are disclosed in document D2 (figure 2). Hence the subject-matter of claim 4 and 5 lacks novelty (Article 33(2) PCT).
6. The additional features of claim 7 are disclosed in document D4 (figures 1 and 2 and column 1, lines 23-25). However it is not consider that a skilled person would combine the teaching of document D1 and D4 in order to arrive at claim 7. Hence the subject-matter of claim 7 appears to involve an inventive step (Article 33(3) PCT).
7. Claims 8-16 are dependent on claim 7 and as such also meet the requirements of the PCT with respect to novelty and inventive step (Article 33(2) and (3) PCT).
8. The additional features of claim 18 are disclosed in document D3 (figure 2 and column 3, line 49 to column 4, line 16). Hence the subject-matter of claim 18 lacks novelty (Article 33(2) PCT).

second issue is that it is not always possible to place discrete actuators as close to each other as required because of their fairly large size.

Against this background, and from a first aspect, the present invention resides in a deformable mirror comprising: a passive substrate layer having a reflective surface provided thereon; a first layer of actively deformable material, attached to the passive substrate layer, that is operable to deform the mirror as a result of transverse expansion or contraction of the material under the influence of a field applied across its thickness; and an actuator coupled to one of said layers that is operable to further deform the mirror. The actuator can be used to provide the basic deformation required of the mirror (e.g. focus), while the deformable material can be used to provide fine tuning of the mirror shape. In this arrangement, the substrate no longer needs to be supported from the edge and so the resonance frequency and bandwidth is increased over and above what it would be for a purely edge-supported device. This means it is possible to concentrate on optimising the design of the deformable material to give the maximum curvature with less constraint from the resonance effects.

Preferably, the deformable mirror comprises a plurality of actuators that support the substrate. Optionally, the actuators are arranged to be operable to correct lower order Zernike modes. Preferably, the layer of deformable material is segmented, the segments being arranged to be operable to correct higher order Zernike modes. Optionally, the deformable material comprises piezoelectric material. Preferably, the actuator comprises magnetostrictive or electrostrictive material.

From a second aspect, the invention resides in a method of correcting phase variations in a beam of electromagnetic radiation incident upon a deformable mirror described above, wherein the actuator or actuators are moved to correct Zernike modes at or below a threshold order and the first and/or second layer or layers of actively deformable material is/are moved to correct Zernike modes above the threshold order. Other preferred, but optional, features of the invention are set out in the appended claims.



- 3a -

In order that the invention can be more readily understood, reference will now be made, by way of example only, to the accompanying drawings in which:

**CLAIMS**

1. A deformable mirror comprising: a passive substrate layer having a  
5 reflective surface provided thereon; a first layer of actively deformable material,  
attached to the passive substrate layer, that is operable to deform the mirror as  
a result of transverse expansion or contraction of the material under the  
influence of a field applied across its thickness; and an actuator coupled to one  
of said layers that is operable to further deform the mirror.
- 10 2. A deformable mirror according to claim 1, wherein the first layer of  
actively deformable material is bonded to the passive substrate layer.
3. A deformable mirror according to claim 1, comprising a second layer of  
15 actively deformable material bonded to the first layer of actively deformable  
material.
4. A deformable mirror according to any one of claims 1, 2 or 3, comprising  
a plurality of actuators, each coupled to one of said layers.
- 20 5. A deformable mirror according to claim 4, wherein the actuators are  
arranged to be operable to correct lower order Zernike modes.
6. A deformable mirror according to any one of the preceding claims,  
25 wherein the first and/or second layer or layers of actively deformable material  
is/are segmented and the segments are arranged to be operable to correct  
higher order Zernike modes.

7. A deformable mirror according to any one of the preceding claims, wherein the first and/or second layer or layers of actively deformable material comprise piezoelectric material and the field is an electric field.
- 5 8. A deformable mirror according to any one of the preceding claims, wherein said actuator or actuators are coupled directly to the passive substrate layer by means of one or more apertures in the first and/or second layer or layers of actively deformable material.
- 10 9. A deformable mirror according to any one of the preceding claims, wherein the actuator or actuators comprise magnetostrictive or electrostrictive material.
- 15 10. A deformable mirror and deformable-mirror holder, comprising a deformable mirror according to any one of the preceding claims and wherein the holder comprises a body with a central aperture for receiving the deformable mirror, the central aperture being defined by a plurality of flexible beams, with each flexible beam having an end shaped to provide a supporting surface and a flexible portion that connects the beam's end to the holder's body.
- 20 11. A deformable mirror and deformable-mirror holder according to claim 10, wherein the ends of the flexible beams are co-joined to form a unitary structure shaped to provide a supporting surface.
- 25 12. A deformable mirror and deformable-mirror holder according to claim 10 or claim 11, wherein the ends of the beams lie in the plane of the body of the holder such that, in use, the mirror is received within the body of the holder.

- 15 -

13. A deformable mirror and deformable-mirror holder according to any one of claims 10 to 12, wherein at least one beam is generally L-shaped such that one leg of the L-shape provides the flexible portion and the other leg of the L-shape provides the supporting surface of the end of the beam.

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14. A deformable mirror and deformable-mirror holder according to claim 13, wherein the internal corner of the L-shaped beam has a shoulder that extends part of the way along both legs of the L-shape.

10 15. A deformable mirror and deformable-mirror holder according to any one of claims 10 to 14, wherein the plurality of flexible beams are arranged around the entire aperture.

15 16. A deformable mirror and deformable-mirror holder according to claim 15, wherein the width of the beams is larger than the separation between beams.

17. A deformable mirror and deformable-mirror holder according to claim 16, wherein the width of the beams is greater than four times the separation between beams.

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18. A deformable mirror and a deformable-mirror holder according to claim 13, wherein the peripheral edge of the mirror is supported from below by one leg of the L-shaped beam and is supported from the side by the other leg of the L-shaped beam.

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19. A deformable mirror and a deformable-mirror holder according to claim 14, wherein the peripheral edge of the mirror is supported from below by one leg of the L-shaped beam and is supported from the side by an inwardly-facing side of the shoulder.

- 16 -

20. A method of correcting phase variations in a beam of electromagnetic radiation incident upon a deformable mirror according to any one of claims 1 to 9, wherein the actuator or actuators are moved to correct Zernike modes at or below a threshold order and the first and/or second layer or layers of actively deformable material is/are moved to correct Zernike modes above the threshold order.

21. A method according to claim 20, wherein the actuator or actuators are moved to correct the first and second order Zernike modes and the deformable element is moved to correct third and higher order Zernike modes.